DECISION SUPPORT SYSTEM FOR TWO DIMENSIONAL CUTTING STOCK PROBLEM

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DEDICATED TO MY PARENTS.

CERTIFICATE

It is certified that the work contained in the thesis entitled "Decision support system for two dimensional cutting stock problem" by P.V.N. Suresh Babu, has been carried out under my supervision and that the work has not been submitted elsewhere for degree.

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ABSTRACT

This thesis describes the design and implementation of an interactive decision support system for two-dimensional cutting stock problem in which rectangular pieces are to be cut from standard size rectangular stocks with the primary objective of minimizing the input material required. One of the major issues considered here is to select the heuristics for the above problem. Two types of heuristics are used for layout generation. One heuristic is used to find the sequence of sheets, when there is more than one type of stock to choose. The other focuses is on displaying the generated solution on the computer screen in a graphical form. Using this the decision maker can appreciate and visualize the layout generated and can also modify it interactively making it a computer aided decision support system. The system has been implemented on an IBM compatible PC /AT under DOS using AutoCAD.

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CHAPTER I

INTRODUCTION

One of the common problems encountered by manufacturers involved in sheet metal industry is to cut a set of small rectangular pieces from limited number of large rectangular sheets, the object being to minimize the waste in the cutting patterns, and thus minimizing the number of sheets used. These problems appear in the cutting of Steel, Wood, Plastics, Glass sheets and in other applications involving cutting operations. The cutting patterns can have severe impacts on the company's profit, especially when material of high value is involved. This is due to the fact that a poor way of cutting may result in a large amount of wastage which, again, means that material and production resources have been wasted. This prompted researchers to attempt solving such problems using a variety of techniques. These problems are referred to in OR literature by varying names like "Trim-loss " or " Cutting stock problems ".

The techniques attempted for this problem can be classified into two groups, viz., Exact and Heuristic methods. An Exact method for a problem guarantees to find the optimal solution. The exact methods have been found to be efficient for a narrow class of applications. The exact methods used for solving trim-loss problems fall mainly into famously known categories of Linear Programming, Dynamic Programming and Branch and Bound. Unfortunately, exact methods for this problem have been proved to be NP-complete (Garey & Jhonson[14]) even

for a single sheet. When the Bill of materials requires several sheets and when there are multiple sheet sizes to choose from, then the case is practically more complicated. Thus, most researchers, instead of trying for exact methods have turned to heuristic solutions.

Heuristic methods cannot guarantee to find the optimal solution and often do not. A heuristic is said to be acceptable in practice if the solution it produces is good enough i.e., with in tolerable range of deviation from optimal solution. Heuristic methods are generally domain oriented, i.e., they use information about particular problem to find optimal solution. Heuristic methods are preferred when it is not feasible to employ algorithmic methods either due to non-availability or prohibitive computational cost.

To make the layout generated by any method to be understandable to the user easily, Computer Graphics are of great use in displaying the layout solution. Techniques have been developed to control NC cutting machines directly with help of the computer generated layout. To take care of real life problems like defective areas, distortion of edges and other technological problems, the use of Interactive system is generally employed.

1.1 DECISION SUPPORT SYSTEMS

Decision Support Systems (DSS) represent a point of view on the role of the computer in the management decision making process. DSS implies the use of computers to :

1. Assist managers in their decision process in semistructured tasks
2. Support, rather than replace, managerial judgment.
3. Improve the effectiveness of decision making rather than its efficiency.

In DSS greater emphasis is not on finding the structure of the problem and automating it, but on Support. Highly repetitive decisions (Structured / semistructured / unstructured) can frequently benefit from DSS. The design of DSS for repetitive decisions differ from non-repetitive in it's approach in dealing with the problem. The general structure of DSS is shown in fig 1.1 and fig 1.2.

The demand for the effectiveness in choosing a method and the necessity of interactive modification of layout necessiates a DSS approach to cutting stock problem.

1.2 CUTTING STOCK PROBLEM

The structural commonality in the cutting stock problem can be summarized as follows.

- A set of orders exists, which demands cut-pieces of certain sizes (order sizes) to be delivered to customers.
- To provide the products required, they have to be cut from larger pieces of material of given sizes known as stocks.
- The cutting process is determined by a specific technology (cutting technology). e.g. guillotine cuts[26].
- Certain properties of the orders, nature of the material and

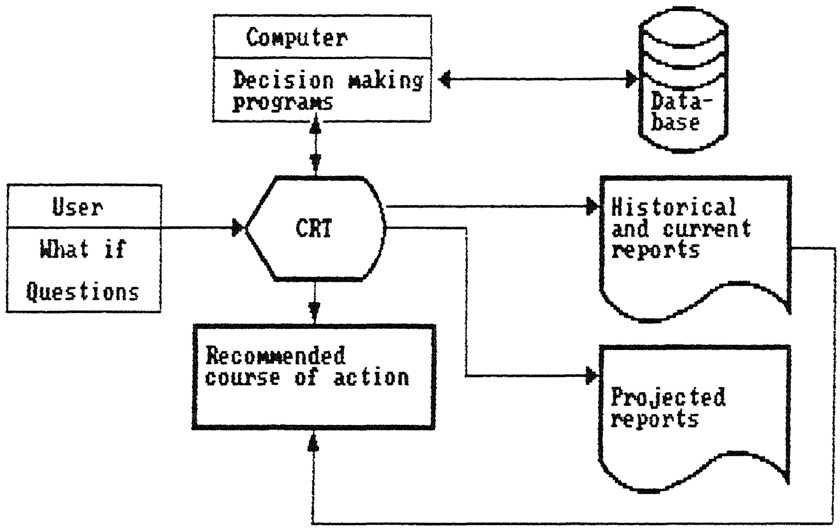


Fig 1.1 Interactive Decision process of DSS

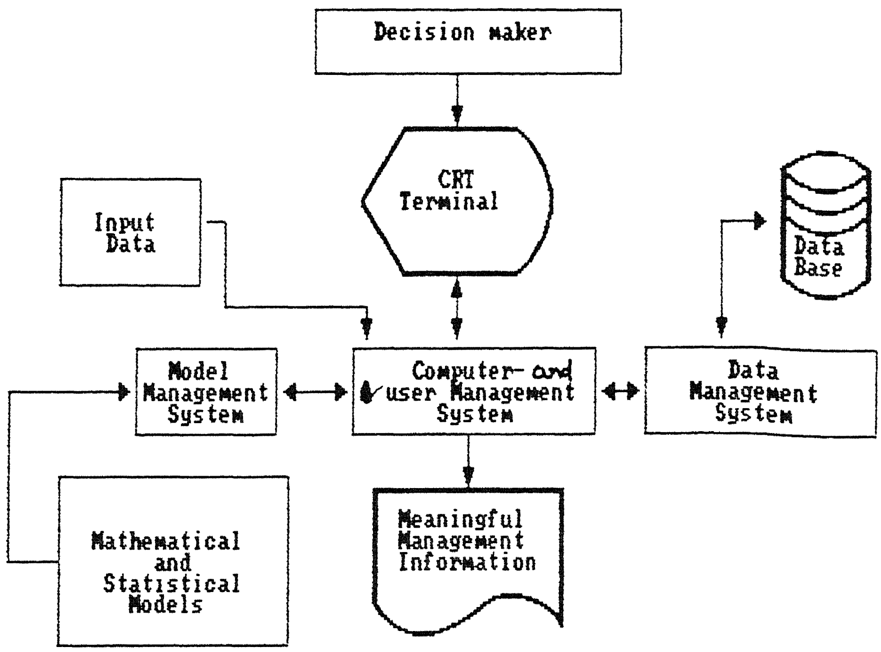


Fig 1.2 Combining data and models in DSS

the cutting technology restrict the number of feasible cutting processes.

- A set of objectives exists for the evaluation of alternative cutting plans.
- A cutting plan has to be derived which satisfies all restrictions and achieves the objectives in the "best" possible way.

In real industrial situations so many factors are to be taken into consideration in deciding the objective. Trim-loss minimization is one of the objectives. The other cost affecting factors are storage , handling of left-overs, over-runs, number of cutting setups and material input. Multi-criterion decision making approach is one of the tools to deal with this type of objectives.

Coming to the general classification, the trim-loss problems can be classified into 1-dimensional, 1-5 dimensional, 2-dimensional, 2.5 dimensional and 3-dimensional problems depending on the relevance of the dimensional factors. 1-dimensional problems are found in situations where stocks of bar or rolls have to be cut into smaller pieces of the same cross section ; in these problems length is the relevant criterion for optimization. In 1.5 dimensional case, the length and breadth are relevant to the trim loss but one of the dimension is fixed and the other is variable. In 2-dimensional case, the given stock is held as a rectangular sheet and customer requirement is rectangles of smaller dimension which is common in glass and steel industries. This

is nothing but CUTTING STOCK problem In the 3-dimensional case, three dimensions viz., length, width and height are relevant to trim loss problem. This problem is also known as LOADING problem.

The trim loss problem can be considered with various restrictions on input and output material and also on cutting technology. The input restrictions can be viewed as the availability restrictions in the quantitative sense and as the material cost in the economic sense. The classification is shown in figure 1.3.

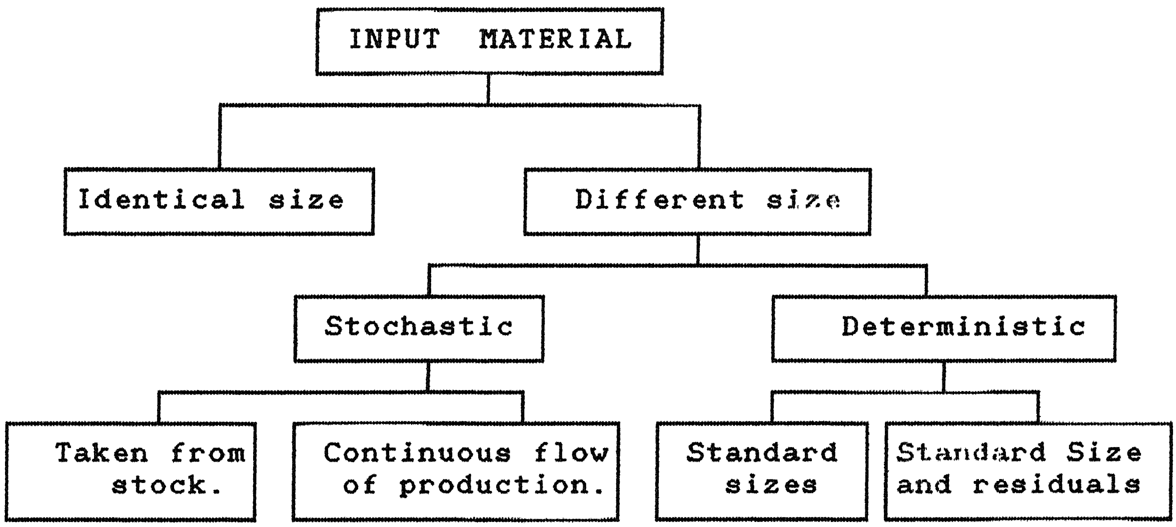


Fig 1.3 : Classification of Input Material.

The output restrictions can be stated as type and quantity of the output produced that comply with demand. The classification of output material is shown in figure 1.4.

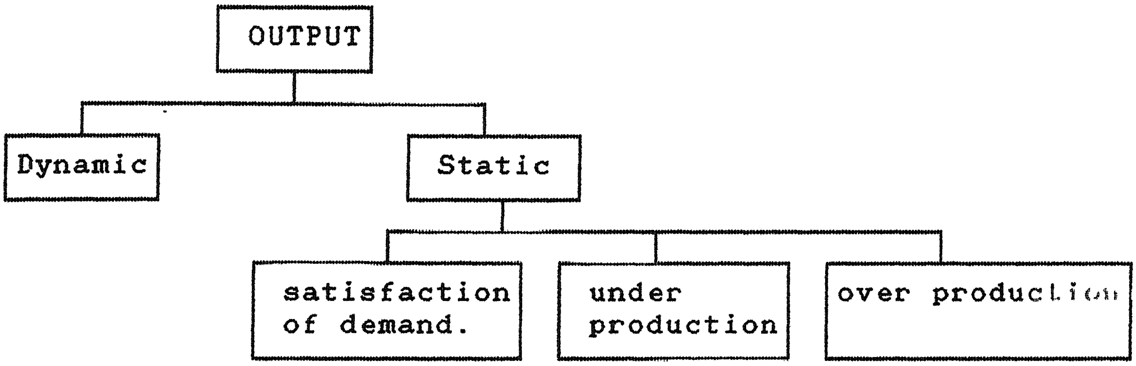


Fig 1.4 Classification of Output.

The cutting and organizational restrictions for these problems may be in the form of meeting each customer's order size at a stretch or in batches, number of pieces on a stock, orthogonal/ non-orthogonal cutting etc.

With reference to rectangular cutting operations, if cuts are made parallel to edges then it is called Orthogonal cutting else it is non-orthogonal cutting.

Orthogonal cutting patterns are further classified into two categories. If cutting technology enables only straight cuts to make from one edge of the material to the opposite one, as is the case in cutting paper with cutting machine or breaking panes of glass, then it is called guillotine cutting. If it is permitted to discontinue the cut at any place in the material then it is called Interlocked-cutting.

1.3 SCOPE OF THE THESIS :

This thesis presents development of an interactive decision support system for a two dimensional trim loss problem. The following assumptions are made in the present

work.

1. The cuts are of guillotine type .
2. The demand for cut pieces is assumed to be static and deterministic. Availability of the stock is the deciding factor in fulfilling the demand.
3. The input stocks available can be of any type; both standard sizes and residuals are allowed.
4. There are no priorities in satisfying the demand.
5. Trim loss is the prime concern in allocation of pieces.

Software has been developed for the user to modify the layout generated, taking into consideration of defects and cutting restrictions. Animation of cutter movement has been provided so as to minimize the cutting length. This prototype leads a way for shop floor implementation. The system has been implemented in AUTOLISP[2] in the AUTOCAD [3] environment so as to provide more flexibility to the user.

1.4 ORGANIZATION OF THE THESIS

In CHAPTER 2, the literature relating to the cutting stock domain has been described. It is organized in the order of developments.

CHAPTER 3 deals with the system design and analysis. In this chapter , the heuristics used to generate layout are discussed, followed by sequence of the cutter path . A brief overview of graphic interface development has been described along with geometric representation , command processing and

the interactive modification commands.

CHAPTER 4 consists of the implementation details of the present system and describes all the functions used in developing DSS. The working of the system is described with an example.

CHAPTER 5 draws conclusions and the suggestions for the possible extension of the present work.

A User manual describing the features of the software appear in the Appendix.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Published literature on trim loss problems appeared around the early 1950's. Since then a number of works have been reported on one dimensional and two dimensional trim loss problems. A brief review of literature for the above problems is described in this chapter.

2.2 ONE DIMENSIONAL PROBLEM

The first mathematical formulation of one dimensional trim-loss problem was done by Kantorvich[23]. Most of the one dimensional problems were treated as Linear programming problems and solved by basic simplex method with some modification by Paul, Walters, Metzger[25] and These methods are found to be suitable for small problems only.

A significance improvement for handling large size problem was achieved by Gilmore and Gomory[16]. Their method involves solving at each pivot stage of simplex method, an auxiliary knapsack problem to determine the successor solution. Because of the computational complexity of the problem generated he introduced a heuristic procedure to solve the problem.

Eismen[13] developed an algorithm taking in to account of re-sale value of the scrap and machine sequencing and it had been applied successfully in the paper Industry. Methods on

branch and bound was considered by Pierce[24] in which there is only one stock length. This method was then applied to deal with restrictions on the number of pieces to be cut, costs related to setting up the cutting machinery and demands that are flexible in a given range. Recently a new LP approach has been suggested by Gerhard Wascher[15] which is formulated based on Multi-criteria decision making.

In addition to algorithmic methods, heuristic methods were considered for problem reduction and saving of computational time. Hassler[19] developed many heuristics for the problems in the paper industry. The basic heuristic of Hassler was utilized for reduction of patterns by introducing aspiration level for occurrence of the cut piece. This method extended to the problems with scheduling of pieces by Coverdale and Wharton[8]. Tokuyama and Uemo[27] present an algorithm which solves a combination cutting stock and stock sequencing problem for one dimensional problems in the Steel Industry.

2.3 TWO DIMENSIONAL PROBLEM

The first algorithmic method for solving two dimensional problem was proposed by Gilmore and Gomory[17] who considered the problem as two stage problem, and at each stage an auxiliary Knapsack problem is solved if cutting patterns are of guillotine cut. Tree search algorithms were proposed by Hertz[22] who developed a powerful recursive procedure with no constraints on the number of pieces to be cut when cuts are of

guillotine type. Christofides and Whitelock[7] developed a tree search algorithms when there is a constraint on the maximum number of pieces that have to be produced. However the performance of these algorithms are not satisfactory in terms of computing time.

Dyson and Gregory[11] adopted Gilmore and Gomory[17] Method for solving problems with breaks in production. He sequenced the order pieces using value based heuristic in which high values are assigned to awkward pieces, and pieces that must be included in solution to avoid production breaks. Adamowicz and Albano[4] considered the cutting stock problem in the ship building Industry by considering ordered rectangles into to strips of one rectangle width using a problem reduction method to find an arrangement of strips which form a cutting pattern. Hinxman[18] also grouped the ordered rectangles by using value heuristics by giving high value to most awkward pieces.

The problem of defects in stock was considered by Hahn[21] considering three stage cutting of sheets using value heuristic with values of the form $a A_p + b A_p^2$ where A_p is the area of the plate. Beasly[6] formulated the cutting stock problem and developed a non guillotine cut tree search procedure for optimizing the trim loss. Sattanathan[26] developed two heuristics for cutting stock problem by using recursive technique. Weishung Qu and Sanders[28] considered the sequence selection of stock sheets in two dimensional layout problems. They have approached the stock sheet selection

problem as a sequential decision problem in which they attempted to solve using Combinatorial optimization methods and associated heuristics.

The advent of Computer Graphics helped people working in this area to take better visiualization of the Layout and then interactively modifying the layout to overcome various restrictions. Albano[1] proposed an interactive system to improve the layout for a two dimensional cutting stock problem in which solution obtained from the system can be modified through few commands.

The present thesis integrates the heuristics and analytical techniques with the help of computer graphics to create a Decision Support System for the cutting stock problem.

CHAPTER III

SYSTEM DESIGN

3.1 INTRODUCTION

The cutting stock problem can be briefly stated as follows. Decide an optimal cutting scheme to cut a set of rectangular plates(called stocks) of length L_i, width W_i and availability A_i. The pieces to be cut are rectangular pieces of length l_k, width w_k and demand d_k. The required demand has to be met from the available stocks. Now our primary objective is to cut the pieces required from the available stocks so that the input material required is minimum. In general there exist some more secondary objectives, wherein one has to optimize the cutting at different stages by considering the cutting technology, storage of material, left-over and sometimes machine life.

Because of the complexity of the problem, the present work considers only primary objective and allows for all the possible cases of production i.e. over-production, satisfying the demand and under-production. In case of over-production provision will be made to cut excess over present demand with the permission of the user so that unused area can be converted into useful plates in future.

In order to build a system to achieve the above mentioned objectives, the selection of techniques to be used plays an important role. The important criterion to be considered before choosing any technique is its ease of use in applying to the

problem and the <u>computational complexity</u>. The difficulty involved in applying the standard LP and Dynamic programming techniques for the present problem led us to explore heuristic procedures.

3.2 HEURISTICS USED

In selecting the heuristics to come up with optimum cutting in any cutting stock problem, two cases of optimization have to be considered. Those are : (a) Optimizing cutting plan within a stock (b) Optimization across several stock types. (stocks of same dimensions are said to be of the same type)

3.2.1 OPTIMIZATION IN A STOCK

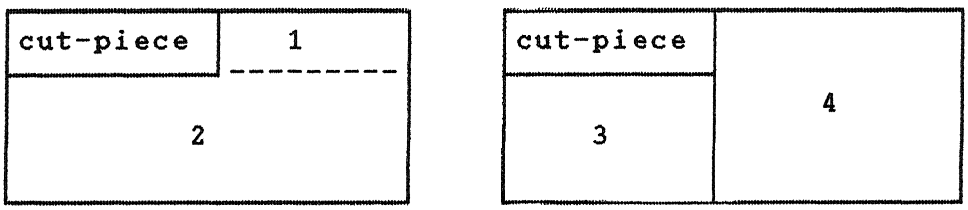
Two heuristics developed by Sattanathan[26] are used in generating the layout. It is reported in [26] that these heuristics are better in terms of computer time and efficiency compared to some of the already existing ones. These heuristics work on recursion. They can be briefly explained as follows.

3.2.1.1. <u>LARGER Heuristic</u> : The cut piece with largest area is selected first and the remaining pieces are allocated to the residual portion of the stock in a recursive manner. This process is repeated until cut pieces are exhausted or the area available in the stock is insufficient to accommodate further pieces. The cuts are assumed to be guillotine cuts.

3.2.1.2. <u>LONGER Heuristic</u>: The piece with maximum length is selected first and the remaining pieces are allocated

recursively in a manner similar to the procedure explained earlier for the LARGER heuristic. The details of the procedures are as follows.

In these heuristics, guillotine cuts are used where the cut starts from one side and traverses in a straight line all the way to the other end of the stock. From the list of cut-pieces, a piece is selected for allocation depending on the heuristic used(LARGER or LONGER). After allocation of piece, the stock can be cut vertically or horizontally as follows.



<u>HORIZONTAL CUT</u> <u>VERTICAL CUT</u>

<u>Fig 3.1 : Type of cuts</u>

In horizontal cut, the cut leaves out two residual pieces on the stock, 1 and 2 as shown in the above figure. It may be noted that one or both the pieces may disappear when the length/width of piece equals the corresponding dimension. In vertical cut the residual pieces obtained are marked as 3 and 4 in the above figure.

Thus after allocation of a piece on the stock, an L-shaped residual is obtained which can be considered as a

combination of two rectangles depending on the cut made.

The residual of stock marked 1, 2, 3 and 4 are considered separately and allocation process is repeated recursively until cut pieces are exhausted or area available in residual is insufficient to allocate more pieces on the residual stock. In each level of recursive allocation, the selection of best cut is made which will give minimum scrap. The recursive procedure is explained as follows.

3.2.1.3 PROCEDURE ALLOCATE;

```
WHILE ((present stock is non zero) and (demand  non zero))
BEGIN
Select the piece that can be allocated in the present stock
 ( This selection of piece will be done based on the piece
  with maximum area/maximum length depending on the
  heuristic used. At each allocation rotate the piece and
  check if the present piece cannot be allocated with
  it's length parallel to stock length.)
 IF piece not allotted THEN
    Compute the trim-loss;
      (The area of present stock is trim loss);
 ELSE
   Find the sub stocks formed after allocation;
   (2-sub stocks for horizontal cut and two for vertical)
  CALL Procedure ALLOCATE For these sub stocks;
  SELECT the cut with minimum Trim loss;
END;
```

3.2.2 OPTIMIZATION ACROSS SEVERAL STOCK TYPES.

3.2.2.1 SEQUENCING OF SHEETS

In the case of multiple stock types, one has a chance of considering any one of them to start with in the cutting process. While cutting, the optimum is of considerable importance. We have considered the heuristic of trying out each plate in sequence. An algorithm which works on top-down approach is used for sequencing of stocks. At each level it selects the node with least percentage trim loss and discards the other nodes and then repeats the same operation for next level till the demand of pieces is completed or availability becomes zero.

3.2.2.2 PROCEDURE SEQUENCE;

```
WHILE (not[(stock availability zero) or (Demand  zero)])
  Begin
          For stock-type 1 to  no-type-stocks
          Generate Layout and find  trim-loss;
           (By calling procedure ALLOCATE)
          Select the stock with minimum  trim-loss;
          Update required parameters;
          Store the optimal allocation;
  End;
```

3.3 INTERACTIVE GRAPHICS

Graphics interface is necessary to display the solution generated by heuristics on a computer terminal so as to allow the user to interact with the system.

3.3.1 GRAPHICS INTERFACE

Major issues involved in developing graphics interface are

1. Geometric Representation
2. Command Processing
3. Interactive Modification Commands.

3.3.1.1 Geometric Representation

Geometric representation of the layout is one of the important issues in providing accurate graphic model to the user. Data structures for two dimensional pictures can be broadly classified into two categories. (a) Topological (or polygon) structure : The two dimensional patterns can be described by points, lines and polygons and are stated in terms of (x,y) co-ordinates. (b) Grid structure : It divides a picture into a rectangular grid where each grid cell contains information about the attribute. Problems like overlapping of two rectangular polygons can easily be handled by grid map. The topological structure has the strength of tracing line and can be applied to various applications. In this thesis topological representation is used.

3.3.2 COMMAND PROCESSING

For a software developed as a decision aid, command processing must be efficient and as simple as possible. Therefore commands for doing various interactive modifications are to be given in a self explanatory menu from which user can

select to modify the layout.

3.3.3 INTERACTIVE MODIFICATION

For interactive modification, sheets are to be considered one at a time and user has to be provided with modification commands. If the layout suggested by the heuristic is acceptable to the user then he need not use any of these modification commands. Interactive modification approach is shown in fig 3.2.

General modification commands necessary are

1.MOVE : To move a piece from one position to another position (represented by its north west corner).

2.ROTATE: To rotate the specified piece through certain angle.

3.INSERT : To insert a piece at a location specified by the user. (The location point will be in the north west corner of the cut-piece) .

4.DELETE : To delete the specified piece from from layout.

5.SETAXIS : To set the axes and starting points.

6.DISPLAY : To display the modified layout.

7.LOSS : To display the loss on the display.

Factors to be considered before designing an interactive system are 1. To provide maximum flexibility and 2. user friendliness to the user in interacting with the system.

3.4 ANIMATION OF CUTTER PATH

This becomes necessary to cut sheets with optimum (or nearer to optimum) cutting length. In actual practice, while

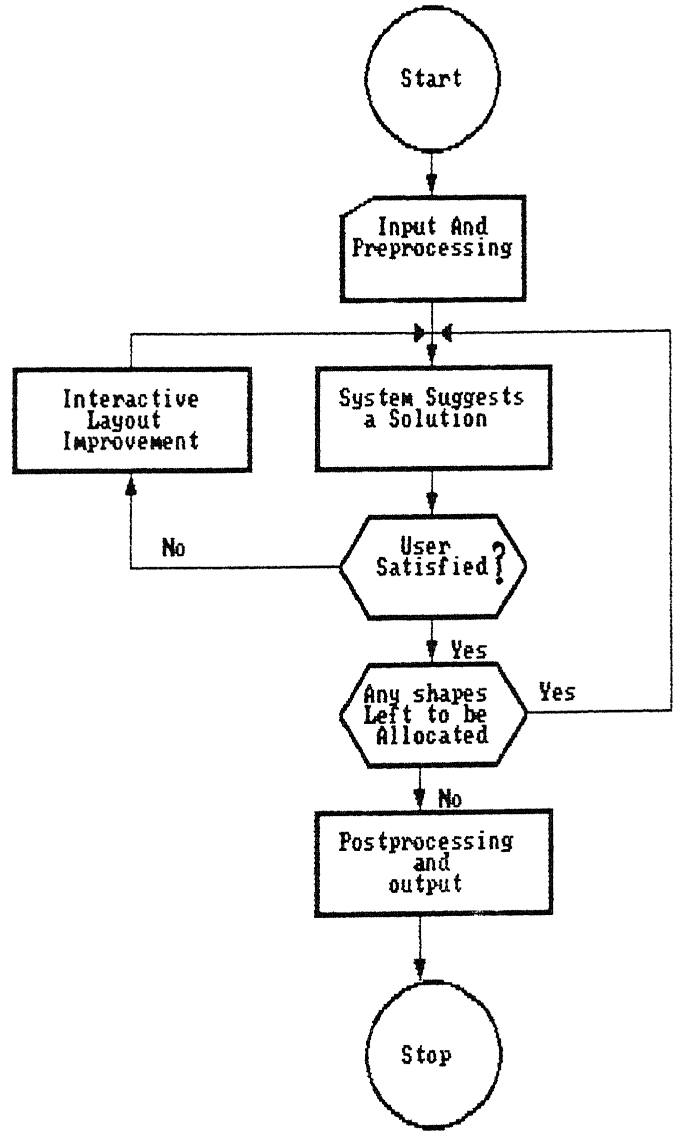


Fig 3.2 Overall solution approcach

finding optimal cutting length, many factors like number of setups and cutting conditions are to be taken into consideration. A heuristic has been used for animation of cutter path.

For a given piece find four edges.

For a given edge

1. Need not cut IF piece edge falls on the stock edge.

ELSE

Check whether this cut already completed;

IF NOT

Check whether a part of this cut has been cut;

Cut the required length of the edge to be cut;

Continue for all edges;

The optimality of this heuristic depends on the way of allocation.

CHAPTER IV

SYSTEM IMPLEMENTATION

4.1 INTRODUCTION

This chapter deals with the system organization and the flow of information taking place between various functions of DSS. The implementation has been done on an IBM compatible PC/AT platform running DOS 3.2 and most of the software is written in AUTOCAD[3] ver 10.0 using AUTOLISP[2]. The reason for the choice of PC is easy availability and the choice of AUTOCAD[3] is flexibility for interactive modification and the powerful interface of AUTOLISP[2].

4.2 SYSTEM ORGANIZATION

The present system consists of four modules. Those are

1. Preprocessing and Input.
2. Optimization.
3. Displaying the layout.
4. Interactive modification.

4.2.1. **PREPROCESSING AND INPUT** : This module takes the data files of cut-piece details, stock details, excess demand (if needed) and the allocation heuristic, the user wants to experiment. This module outputs the cutting schedule based on the heuristic selected. The system asks the user whether he is interested in allowing for overproduction. In case of overproduction, if different percentages of overproduction is

decided for different types of pieces, then all these percentages will be read from a file specified by the user. Otherwise, the user can specify a fixed percentage (say 15 %)of overproduction for all types of pieces required. Later, the user is expected to suggest the type of heuristic (LARGER or LONGER) that has to be used for allocation. This list is the input to generate allocation. The structure of entering data into a text file is shown in the example problem which is given at the end of this chapter (table 4.2). The autolisp function developed to perform the above operation is READ-DATA ().

4.2.2 OPTIMIZATION :

The optimization in this problem can be treated in two stages. (a) Optimizing the cutting with in a stock and (b) Optimal allocation across several stock types. The first case arises when all the available stocks are of same type (we refer stocks with same dimensions as one type). In this case we have to optimize the allocation with in the stock. The second case arises when the stocks available can be of different types. In this case we have to optimize the stock selection as well as allocation. The stock selection is done by the function SEQUENCE and the allocation with in a stock by FIND_TRIM_LOSS. Both are recursive functions. The input to the FIND_TRIM_LOSS is stock dimensions and the demand to be met. The input to the function SEQUENCE is the availability and the demand to be met. The function SEQUENCE calls the function FIND_TRIM_LOSS to fulfill two stage optimization. The output after this optimization process is a list of stocks allocated and

allocation on them.

i.e., List of (stock-length stock-breadth (allocation on it)) and Allocation on any stock is list of (starting-point length-of-piece breadth-of-piece).

4.2.3 DISPLAYING THE SOLUTION : The flexibility to program through AUTOLISP[2] to access its parameters like settings, limits, dimensions and colors has been provided by AUTOCAD[3]. In this present implementation each allocated stock is represented by a AutoCAD LAYER[3] and the pieces allocated on it by AutoCAD SOLIDS[3].

The input to this module is the output generated from the previous module. From the total allocation, this module takes each stock and sets the settings and dimensions. This process will continue for all the pieces in a stock. Then, it switches over to different layer (to represent another stock) and continues the above process. The above mentioned operation will be done by the function (INTER_ALLO). The output from this module is a file with the layers drawn.

4.2.4 INTERACTIVE MODIFICATION: To select any layer[3], from the output generated by the previous module the command SET-LAYER is used. All the commands necessary and their syntax have been discussed in the APPENDIX. The major commands necessary for interactive modification are given below.

1. MOVE
2. ROTATE
3. ERASE
4. DR-BOX
5. INSERT
6. REDRAW
7. UNDO
8. END
9. QUIT
10. SAVE
11. LOSS
12. ANIMATE

The command MOVE is used to move a piece to a specific point (a point corresponds to north west corner of the piece); The command ROTATE is used to rotate a piece by any angle; ERASE is used to erase a particular piece or region; DR-BOX is used to draw a solid to add a new piece; REDRAW is used to redraw a drawing after editing; UNDO is used to undo any operation performed in the interactive modification. END saves and quits from editing where as QUIT is used to discard the changes to the drawing. SAVE is useful to save a drawing without quitting the editing screen.

The command LOSS is used to calculate the percentage of trim loss whenever pieces are added/deleted from the stock. The calculation of loss has been done by reading all the solids[3] of different colors which represent the pieces and the stock size. The extracted objects are to be processed to calculate the percentage loss. This will be displayed in the topmost right hand side corner. The function to perform the above operation is LOSS.LSP.

The command ANIMATE is used to show the cutter path to be followed. This works by reading the solids on the layer and

sequences based on the heuristic followed in allocation. The procedure followed to ANIMATE has been described in chapter 3. The function to perform the above operation is ANIMATE.LSP. Alternatively output can be had in tabular form also.

4.3 FILES USED:

1. Thesis.lsp (/* Which performs the reading input, Layout generation, displaying the solution)
2. Loss.lsp (/* which calculates the loss when needed)
3. Animate.lsp (/* To animate the cutter path)
4. Acad.mnu (/* Present menu file)
5. Dsscut.lsp (/* which runs the program)
6. Acad.lsp (/* which starts by loading all the files)

4.4 EXAMPLE PROBLEM : The problem is described as follows.

Availability of stocks data:

Type	length	breadth	number available
1	10	10	1
2	12	10	1

Demand of pieces to cut :

Type	length	breadth	number required
1	10	2	2
2	7	3	2
3	6	4	1
4	4	4	3
5	5	5	1

```
The format to enter data in the input file;
 2                 ;number of stock types
 5                ; number of piece types
(10 10 1)       ;(length breadth availability) of a stocktype.
(12 10 1)
(10 2 2)           ;(length breadth required) of a piece type.
(7 3 2)
(6 4 1)
(4 4 3)
 (5 5 1)
```

Table 4.2 : Format of entering input data in a data file.

The output generated after optimization module is shown in fig 4.1, 4.2, 4.3, 4.4, 4.5.

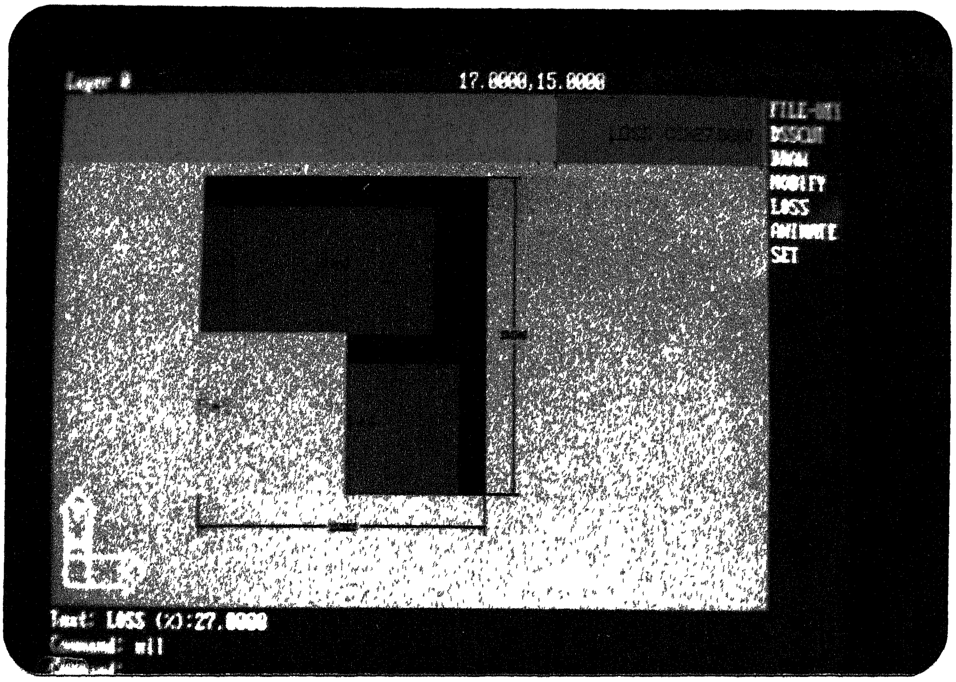


Fig 4.1 : Example problem for LARGER

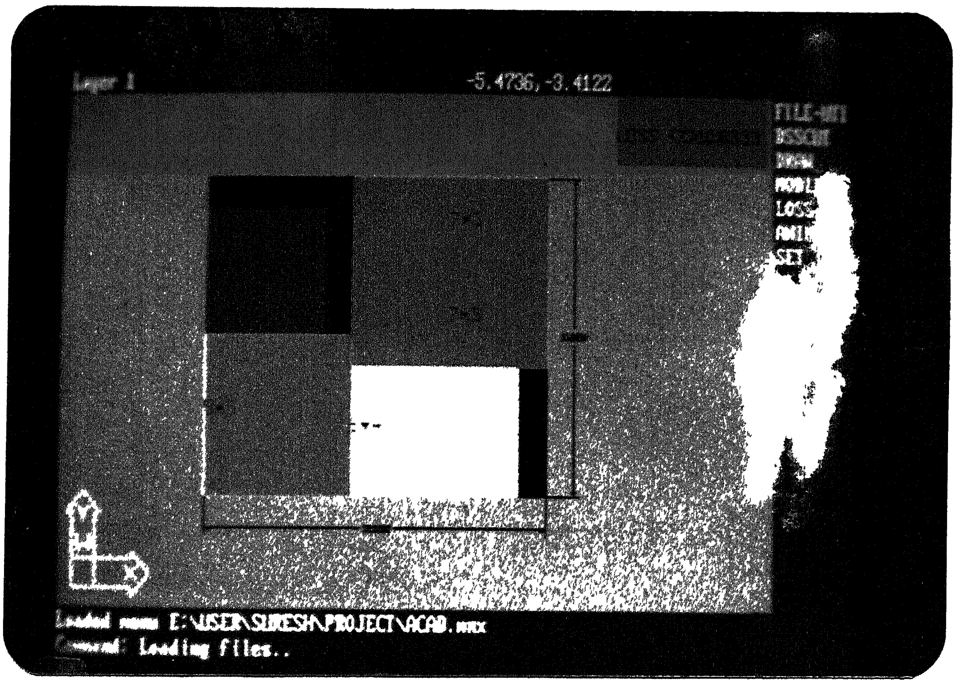


Fig 4.2 : Example problem for LARGER (contd.)

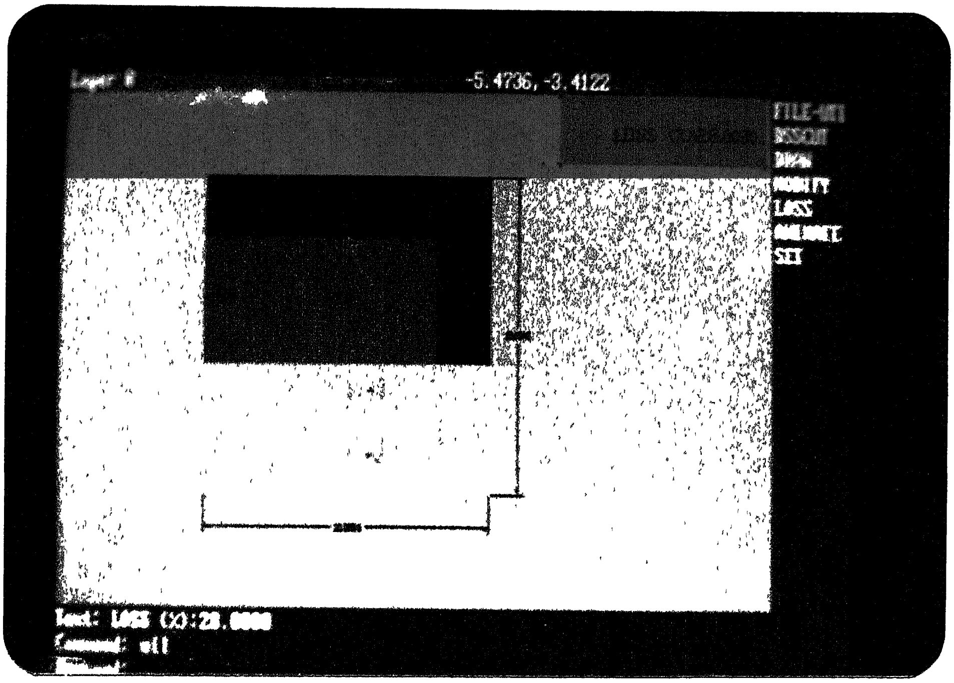


Fig 4.3: <u>Example problem for LONGER</u>

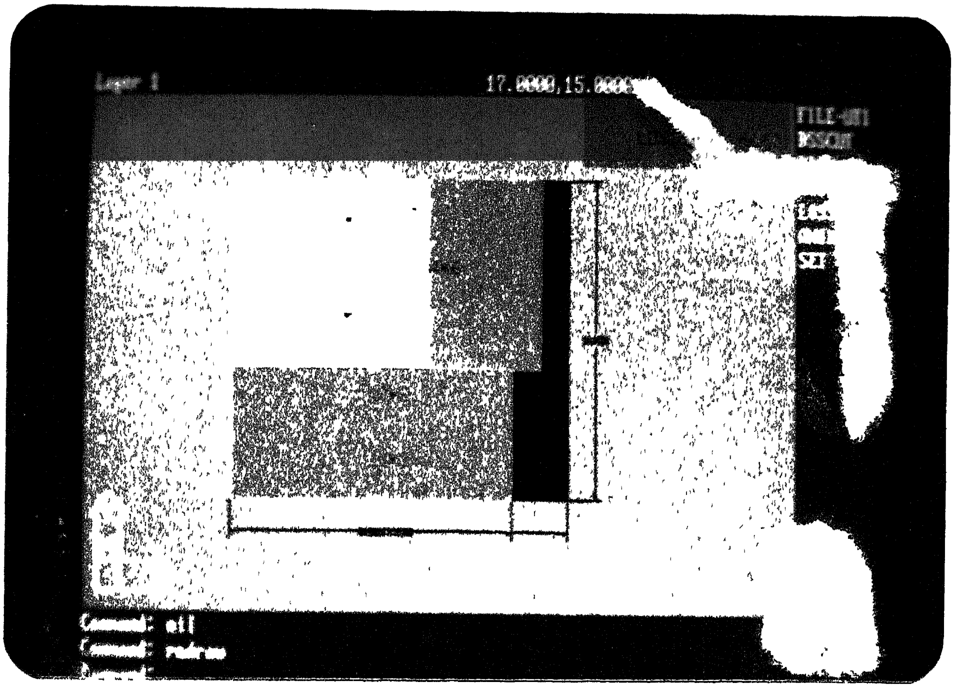


Fig 4.4 : Example problem for LONGER (contd.)

Fig 4.5 : Modification of a piece

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In the present thesis, an attempt has been made for developing a Decision Support System for one of the important problems faced by industries related with cutting of stocks. The major emphasis is given to apply heuristic and interactive techniques to the two dimensional cutting stock problems. Two heuristics have been used in generating the layout, which are reported an improvement over one proposed by Hertz[22].

The selection of AUTOLISP[2] as a programming tool is slow in PC's. In this work more emphasis is given to provide interactive modification facility to the user. This approach uses computer graphics and analytical techniques to support the decision, to the decision maker. The adoption of AUTOCAD[3] as a graphic tool has given more flexibility in terms of user interface.

5.2 SCOPE FOR FUTURE WORK : Further work can be carried out as described here.

1. Better heuristics can be developed to reduce the computation time. Some of the value based heuristics can be tried wherein one has to assign priorities based on some value based utility or due dates.

2. The objective considered is only the trim-loss minimization.

There is a possibility of developing a DSS by considering the number of setups, cutting technology, holding and left-over costs with the help of multi-criterion decision making.

3. The functionality of the graphical interface can be enhanced so that it can automatically check, given the layout whether it is optimal or not.

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APPENDIX

USER'S MANUAL

To work with AUTOCAD[3], you need a work station or PC/AT with color monitor that can run AUTOCAD release 10.0. To run AUTOLISP [2] you need to have the following .

1. An 80286 or 80386 processor based computer.
2. 640k memory plus 1MB or more extended or expanded RAM.
3. Hard disk with 20MB or more disk capacity.

A.1 ENTERING INTO AUTOCAD :

Assuming that you have loaded AUTOCAD in the E drive of PC /AT, you can enter in by typing

E: \ AUTOCAD \ ACAD

If you are in your own directory set path to the above mentioned directory from your sub directory.

In the present case from E: \ user\ suresh type CAD.BAT to enable AUTOLISP to run. CAD.BAT consists of setting various parameters to enable AUTOLISP.

A.2 BATCH FILE CAD.BAT

```
SET PATH=E:\ AUTOCAD \ ACAD
SET LISPSTACK=40000
SET LISPHEAP=5000
SET LISPXMEM=0, 1024K
EXTLISP
ACAD
```

Now you can see the following options which are self

explanatory.

0: Exit AUTOCAD

1: Begin a new drawing.

2: Edit an existing drawing.

3: Plot drawing.

4: Printer plot drawing.

5: Configure AUTOCAD

6: File utilities.

7: Compile shape font description file.

8: Convert old drawing.

Give option 1 and corresponding file name. Later you can see the menu of the present thesis along with command prompt. At this stage it will load all the files relevant to the system.

If you have the input data-file (with specified format shown in the previous chapter), select option DSSCUT to run this package, which asks for input file name, extra demand file name (if allowed) and the heuristic to be selected for allocation. It automatically solves and allocates on the LAYERS treating LAYERS as stocks and SOLIDS as pieces. When solving is completed you can see the command prompt .

To select a particular stock for interactive modification select that particular layer or layer starting with 0 by selecting SET-LAYER from menu structure. Now you can see the layer with allocation and the percentage loss in that particular stock. A brief description of Interactive

modification commands is given here.

A.3 MODIFICATION COMMANDS:

Before using any modification command, the selection of objects becomes necessary.

A.3.1 Selecting objects: There are about twelve ways of selecting the objects from a layer for editing, but now we need only two types of selection.

1. Window :selects by grouping objects together in a window.
2. Last :selects the last object added to the selection set.
3. Previous :selects the entire previous selection set.

A.3.2 COMMANDS

A.3.2.1 MOVE Command : Move is used to translate one object from one position to other position. MOVE the SOLID (piece) selecting by window option. When you are prompted for a base point or displacement, pick a base point. After you pick the point, the selection set images will drag with your pointer. Pick your second displacement point, using the coordinate values.

MOVE command can be applied like this.

command: MOVE

Select objects: W (to select window)

First corner : (starting coordinate of the window)

other corner : (diagonal coordinate of coordinate 1)

Select objects: (telling AUTOCAD that selection over)<return>

Base point or displacement: Pick any point on the solid.

Second point of displacement: Pick the point to which the previously specified point to move.

When you finish, you can see the part moved. You can select the points by cross hairs or by giving co-ordinates.

A.3.2.2 <u>ROTATE command:</u> The ROTATE command lets you turn at precise angles. Like MOVE , you specify a first point as a base point. This is the rotation base point. The rotation base point need not be a point on the object to be rotated. You can select any where and AUTOCAD will rotate entities with respect to the base point. After base point you have to specify the angle. The negative angles produce clockwise rotation where as positive angles produce anti-clockwise rotation.

Command: ROTATE

Select objects: W (As explained for MOVE)

Base point : (select point as explained above)

Rotation angle: (-ve angle for clockwise, +ve angle for anti clock wise)

A.3.2.3 <u>ERASE</u> command : ERASE command is useful in deleting any objects from the drawing. Here, you have to select the entities to be deleted from the drawing. If you want the entity erased to be restored use OOPS command.

Command : ERASE

Select the objects: (select as explained earlier)

Select objects: (After selecting all press <RETURN> to erase)

A.3.2.4 INSERT command: This command is useful in inserting any object in the drawing. In our present thesis you can insert any piece if the available space is sufficient to insert any entity. Define the entity to be inserted as block before calling INSERT. This can be done by command BLOCK.

command: INSERT

Block name: (Give the name of the earlier defined block)

Insertion point :(pick absolute insertion point)

X scale factor :<return>

Y scale factor : <return>

Rotation angle: <return>

A.3.2.5 DR-BOX command: This is used to to append any piece to the stock. This asks the starting point, length and breadth. It draws the SOLID filled with a color representing the piece. You have to specify the color corresponding to that particular piece.

Command: DR-BOX

Enter starting point:

Enter length:

Enter breadth:

Enter color:(code of the color)

A.3.2.6 <u>UNDO command</u>: UNDO command is used to erase the previously done operations. The command U erases a set of previous operation like ERASE. There are several options for UNDO.

Command :UNDO

Auto /back /control /end /group /mark /<number> : (these options indicates various ways of using UNDO which are self explanatory.)

A.3.2.7 <u>SET-LAYER Command:</u> This command is used in selecting a particular layer as current layer. Here you have to specify the number of the layer to make current. This function sets to this layer and make others to be off.

Command: SET_LAYER

Enter the number of the layer to make current:

A.3.2.8 <u>LOSS command</u> : This command is useful whenever you want to know about the percentage loss in a particular stock (here layer). You just have to call this command.

Command: LOSS

A.3.2.9 <u>ANIMATE command</u>: This command is useful in finding the cutter path to be followed. This will be shown by a cross moving along the cut. Here you have to specify the length and breadth of the present stock. This is the constraint of this command.

Command: ANIMATE

Enter the length of the stock:

Enter the breadth of the stock:

A.3.2.10 <u>END command</u>: This command saves the present drawing and quits the editing section.

A.3.2.11 <u>SAVE command</u>: This command is used to save the present drawing.

Command :SAVE

File name:

A.3.2.12 <u>QUIT command</u>: It is used to discard the changes to the present file and to quit the AUTOCAD.